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MANIFESTATION OF ECOLOGICAL-ADAPTIVE PROPERTIES OF SOYBEAN VARIETIES DEPENDING ON SOIL-CLIMATIC CONDITIONS

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ABSTRACT

The research results of evaluating soybean varieties by adaptability (ecological plasticity and stability) in different soil-climatic conditions have been presented considering the resistance to disease (fusarium, bacteriosis). The soybean varieties have been ranked by ecological plasticity and stability in accordance with their reaction to environmental factors. In terms of resistance to fusarium during the research period, in different ecogradients of varieties Hoverla – 86,6%, Oriana – 83,7% and Vezha – 81,2% have revealed themselves. Higher rates of resistance to fusarium have been provided by varieties with different reactions to changes in environmental conditions. The Hoverla variety belongs to the first rank, the coefficient of ecological plasticity (bi) – 0,38, that is, < 1, and the variance of stability (S^2) > 0. Vezha and Oriana varieties belong to the sixth rank in terms of the reaction of growing them in different ecogradients, the coefficient of ecological plasticity (bi) is 1,12 and 1,3, and the variance of stability (S^2) > 0. In terms of resistance to bacteriosis, soybean varieties of Hoverla – 84,1%, Oriana – 81,7%, Vezha – 79,7 and Femida – 78,6% have been noted. Varieties Oriana, Vezha and Femida belong to the highly plastic in reaction to changes in growing conditions, (bi) > 1, and variety Hoverla is conservative in reaction to changes in hydrothermal and soil growing conditions (bi) < 1. Variety Hoverla has been distinguished by a slight reaction to changes in environmental conditions, providing a high stable indicator of resistance to both fusarium and bacteriosis, and varieties Oriana and Vezha to highly plastic, which respond well to improved growing conditions. However, considering the highest quantitative values of disease resistance of these varieties in different ecogradients, they belong to the adaptive ones.

Key words: soybean, varieties, ecological plasticity, stability, adaptability, environment, fusarium, bacteriosis.

INTRODUCTION

The development of the biosphere and society takes place in an inseparable coevolutionary relationship, the full existence of which is possible only in case of following the principles of the «ecological imperative», that is based on the harmonious coexistence of man and the environment (Nezhadahmadi et al., 2013). Adherence to ecocentric principles will halt the degradation of ecosystems, including anthropogenic ones, the negative impact of which is growing, becoming increasingly global (Field et al., 2014).

One of the ways to reduce the negative impact on the environment, to preserve and increase biodiversity is the introduction of resistant and adaptive forms and plant species that are able to withstand negative abiotic and biotic factors to a greater extent. The created plant forms lose their biopotential over time, including adaptive capabilities, that is why the replenishment of anthropogenic ecosystems with a new adaptive assortment, particularly due to modern climate change, is relevant (Kolupaiev, 2001).

The basis of plant resistance are the mechanisms of adaptability, the study of which, despite the significant achievements of developments, attracts more and more attention of researchers. The importance of the research in this area is determined not only by possible risks of their death or productivity decrease in certain years, but also by withstanding stressors which occur more and more often (Andresen et al., 2007; Bita et al., 2013).

Worsening of the ecological situation and the decrease in biodiversity, the rational use of its components, including cultivated plant species, is becoming increasingly important, not only as a key autotrophic component and the most energetically active link in all ecosystem processes of the biosphere, but also a convenient object of environmental researches (Didur et al., 2020). Solving the above mentioned problems, a number of ways and approaches to improving the state of the environment have already been suggested and they still continue to be developed. A significant proportion of the planet is occupied by anthropogenically transformed ecosystems, the sustainable use of which often includes anthropocentric approaches (Mazur et al., 2021). In recent decades the current environmental crisis has drawn prompt attention to biocentric approaches, in which the ecological imperative is not the subordination of nature to human interests, but coordination, a harmonious combination of human activity and the laws of nature. Such development of relations is preceded by a model that would solve conceptual problems due to forecasts, directing further actions towards the dynamic equilibrium of processes in ecosystems and optimisation of the life state of biodiversity (Razanov et al., 2020).

The management of the plant vitality within certain ecosystems, for which methods and concepts based on a complex of structural and functional features of adaptation changes, as adaptive mechanisms to environmental conditions, do not lose their relevance (Kordium et al., 2015). An important stage in expanding the functionality and harmonisation of vegetation with the conditions for existence is the consideration of the responses of plants to their adaptations to a certain amplitude of environmental factors' fluctuations at different levels of integration of living matter (Tkachuk et al., 2021).

Thus, the adaptability of plant populations to environmental factors is a necessary condition for their existence, adaptability strategies according to differentiated and integral features that will determine the prospects for the competitiveness of plants in the ecosystem and the mechanisms of population ordination relative to other components of ecosystems (Yanovych et al., 2018).

The plant organism, as a complex hierarchically subordinate system, is capable of self-regulation and self-reproduction. Each plant is differently demanding on temperature, water, air, soil, light, nutrient regimes. Each variety is adapted to a specific set of environmental conditions – and has its own ecological niche in the biocenosis or in the biosphere as a whole. (Varchenko et al., 2020).

In the process of adaptation of living organisms and populations to environmental conditions, their vitality is determined by limiting abiotic and biotic factors which form the structural-functional organisation, productivity of the biocenosis and ecosystem particularly (Kaletnik et al., 2020).

In the realization of plant potential in specific conditions the optimal value of environmental parameters, at which the highest indicators of viability of the plant species are observed, takes a special place. And if natural species grow in favourable soil-climatic conditions, then for artificially created plant forms, a person selects such conditions, or finds the desired genotype (Kiyak, 2014).

Considering the current global climate change and significant anthropogenic pressure, an ecosystem approach to building sustainable adaptive agroecosystems with a favourable phytosanitary and ecological state is becoming increasingly practical (Palamarchuk et al., 2021).

The extremely high intensification of technologies for growing and creating crops brings the actual harvest closer to the genetic potential inherent in the genotypes of plant varieties. However, the use of a wide range of chemical plant protection products, mineral fertilisers significantly increases environmental pollution, the accumulation of harmful substances in agricultural products. This leads to an aggravation of the stability of the functioning of ecosystems and the preservation of the natural environment. One of the ways of solving this situation is to create ecologically adaptive varieties that are resistant to disease damage, which will help reduce the use of chemical pesticides, that is, the effect of anthropogenic pressure on the environment (Honcharuk et al., 2021).

The basis of the stability and adaptive features of plants reveals itself in the mechanisms of adaptability, the research of which, despite the significant achievements of developments, is quite relevant today (Moskalets et al., 2016).

The study and creation of cultivars and varieties of plant species, which form stable vegetative and generative productivity under adverse and extremely unfavourable environmental conditions due to their greater value compared to those that have high seed productivity only in weather-friendly years, have recently become increasingly important (Zaitseva, 2015). In this regard, the success of introducing new species, including crops, is possible only in case of considering the mechanisms of viability – priority criteria of adaptability, which will contribute to the enrichment and preservation of biological diversity, rational use of natural resources (Loreau et al., 2013).

Environmental conditions are variable and cause genetic adaptations to certain conditions in plants. The plants are constantly exposed to adverse environmental factors: temperature fluctuations, drought, excessive moisture, salinity, acidification, contamination with toxic substances, etc., each particular plant organism is able to adapt to these conditions only within the limits caused by its genotype. The higher the ability of a species to change metabolism according to the ranges of changing conditions, the wider the rate of its reaction and the higher the ecological-adaptive capacity (Yaropud et al., 2022).

Ecological plasticity is the ability of a variety to use effectively favourable environmental factors. Ecological stability reveals itself as the ability of a variety to withstand stress factors. The degree of reaction of genotypes to changes in environmental conditions is characterised by a coefficient of ecological plasticity, which reflects the direction and level of changes in individual indicators of the variety relative to the adaptive norm (average rate of reaction) (Biliavska et al., 2021).

The trait plasticity appears as an independent property and is under specific genetic control. The stability and plasticity of agronomic traits of plant species varieties are determined by the ability of plant genetic mechanisms to minimise the effects of negative environmental influences, that is, to resist them. Plasticity is a measure and direction of the genotype response to fluctuations in environmental conditions. Stability – sustainability of implementing the inherent genotype's reaction to changes in environmental conditions. The interpretation of the terms «stability» and «plasticity» by different authors is ambiguous, but their biological meaning coincides (Tkachuk et al., 2021).

Significant developments on the issues of plant cultivars' sustainability to environmental conditions at local levels have been obtained by scientists M. Lonbani, 2011; A. Arzani, 2014; D. Lobell et al., 2021.

The general tendency of adaptability of cultivated species to certain growing conditions is usually defined by the regression coefficient. The stability of the genotype is calculated by the difference between the maximum and minimum yield and, the lower it is, the higher the stability (stress resistance). An intensive variety is considered to be one that, under optimal growing conditions, each year prevails in seed productivity of all those researched; plastic (capable of variability) is a variety that provides the highest average productivity under different conditions in years of conducting the experiments; a stable variety is the one that has the smallest difference between the maximum and minimum yields, an adaptive variety forms a consistently high, relative to other varieties, seed productivity with genetically determined quality in a wide range of changing weather and anthropogenic conditions (Razanov et al., 2018).

Adaptability corresponds to the content of the parameters of ecological plasticity. The adaptive properties of cultivated plant species determine the stability of seed productivity, especially in adverse years (Honcharuk et al., 2021).

The aim of the research is to determine the ecological and adaptive value of soybean varieties in terms of plasticity and stability by testing them in different ecogradients according to the hydrothermal regime and soil conditions.

MATERIALS AND METHODS

During 2010-2021 the research was conducted under conditions that contrastingly differed in hydrothermal regime and soil conditions at varietal testing points, which are localised in different soil and climatic subzones of Ukraine. This provided a study of the reaction of soybean varieties to the amplitude of environmental factors' variability. Soils were represented by typical black soils in Kyiv region, podzolic black soils in Poltava region and grey forest soils in Vinnytsia region. For an objective assessment of the genetic potential of soybean varieties and their reaction to changes in the hydrothermal regime in different soil conditions, determination of ecological plasticity was carried out on the basis of disease resistance.

The research object was soybean varieties: Amethyst, Hoverla, Artemida, Femida, Zolotysta, Vezha and Oriana, which are included in State Registration of Plant Varieties suitable for distribution in Ukraine.

The research was conducted according to the standard method. Accounting for disease damage was carried out at the phases of growth and development of plants during the growing season according to the proportion of the damaged surface in percentage (Methodology, 2011).

One of the main complex methods of analysis is to determine the stability and ecological plasticity of the researched varieties, which has been carried out according to the Eberhard-Russell method. This technique enables variety evaluations not only by the values of averages, but also by plasticity (b), that reflects the regression of the variety to changes in environmental conditions and the stability (Si^2) of this reaction.

In the used methodology to generalise the experimental data, the sum of the squares of interaction of each variety with the conditions of the medium is divided into two parts – the linear regression component (b) and the nonlinear part, which is determined by the root mean square deviation from the regression line (Si^2) (Methodology, 2011).

According to the calculation results of plasticity (bi) and stability indicators (Si^2), the following grouping ranks have been distinguished for varieties: 1) indicators $B < 1$, $Si^2 > 0$ – have better results under adverse conditions and characterise the variety as «unstable»; 2) indicators $B < 1$, $Si^2 = 0$ – have the best results under adverse conditions and define the variety as «stable»; 3) indicators $bi = 1$, $Si^2 = 0$ – respond well to the improved conditions, and have an evaluation rating of «stable»; 4) indicators $bi = 1$, $Si^2 > 0$ – respond well to the improved conditions and characterise the variety as «unstable»; 5) indicators $B > 1$, $Si^2 = 0$ – have the best results under favourable conditions and define the variety as «stable»; 6) indicators $B > 1$, $Si^2 > 0$ – have the best results under favourable conditions and define the variety as «unstable» (Methodology, 2011).

RESULTS AND DISCUSSION

In our studies, significant differences in precipitation (Fig. 1) and hydrothermal coefficient (Fig. 2) have been identified, that enables conducting reliable evaluation of varieties according to the parameters of ecological plasticity and stability.

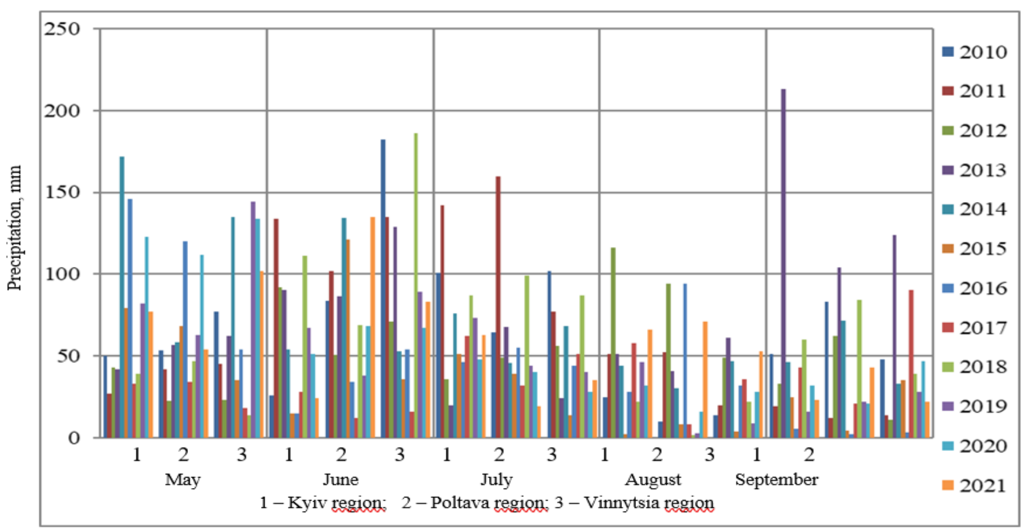

Figure 1. Amount of precipitation during the growing season (BBCH-10-99).

Less favourable conditions for the growing season of soybeans in all researched soil and climatic subzones were noted in 2015, 2019, 2020. Particularly, under the conditions of Kyiv region, the hydrothermal coefficient was 0,47, 0,51, 0,5, respectively. In Poltava region, it was 0,86, 0,75, 0,9, respectively, and in Vinnytsia region it was 0,83, 0,73, 0,9, respectively. At the same time, the average long-term indicators of the hydrothermal coefficient for the subzone of Kyiv region are 0,95, for Poltava region – 1,05, for Vinnytsia region – 1,07, that influenced the formation of contrast resistant values of soybean varieties to fusarium in different soil-climatic conditions of the research (Table 1).

The influence of genotype and soil-climatic conditions and their combination in a separate variance of statistical processing of the results of resistance to fusarium by conducting a two-factor dispersion analysis made it possible to determine the substantiality of the difference according to the Fisher criterion.
Considering the resistant indicators to fusarium during the research years, in different ecogradients, it should be noted the following varieties: Hoverla – 86,6%, Oriana – 83,7% and Vezha – 81,2%. It should also be mentioned that higher rates of stable characteristics have been provided by varieties with different reactions to changes in environmental conditions.

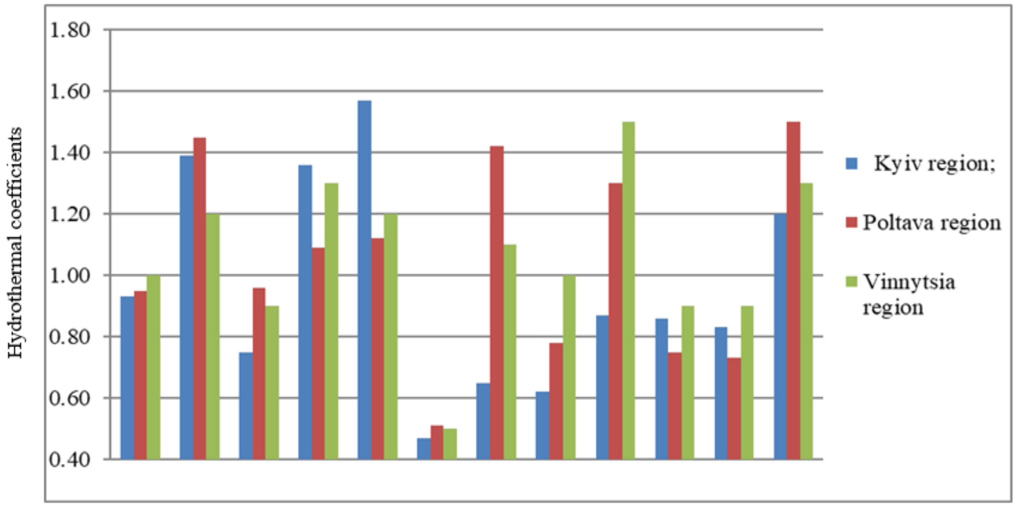

Figure 2. Hydrothermal coefficients during the growing season (BBCH-10-99) (May-September) 2010–2021.

Table 1. Ecological plasticity and stability of soybean varieties in resistance to fusarium, % (2010-2021).

Variety	Resistance to fusarium, %	Coefficient			Stability variance (Si^2)	Hom-homeostaticity	Components	
	Year, trial sites	Ecological plasticity (bi)	Agronomic stability (As), %	Variances (V), %		Hom	a_i	λ_i
Amethyst	79,4	0,96	96,0	4,0	6,9	19,8	0,06	0,67
Hoverla	86,6	0,38	97,1	2,9	5,7	30,3	-0,14	0,60
Artemida	78,8	1,27	95,5	4,5	5,5	17,6	0,19	0,39
Femida	77,2	1,11	95,9	4,1	5,3	18,8	0,13	0,39
Zolotysta	74,3	0,89	95,8	4,2	8,1	17,8	0,04	0,50
Vezha	81,2	1,12	96,5	3,5	3,1	22,9	0,13	0,28
Oriana	83,7	1,3	96,0	4,0	4,5	21,1	0,18	0,44
Factor	F ф	F т			-	-		
Variety	855,6	2,19			-	-		
Conditions	512,0	1,54			-	-		
Interaction variety - conditions	30,6	1,39			-	-		

So, the Hoverla variety belongs to the first rank due to the above presented classification of grouping ranks, the coefficient of ecological plasticity (bi) of the Hoverla variety is 0,38, and the stability variance (S^2) > 0 indicates that this variety was marked by a conservative reaction to changes in environmental conditions, providing better indicators of stable characteristics both for improving and worsening the hydrothermal regime of growing conditions. The Vezha and Oriana soybean varieties belong to the sixth rank in terms of the reaction of growing them in different ecogradients, the coefficient of ecological plasticity (bi) of the Vezha variety was 1,12, and the Oriana variety was 1,3, the stability variance (S^2) > 0. These varieties have the highest rates of agronomic stability (As) = 96,0-97,1% and the lowest indicators of the coefficient of variation (V, %) – from 2,9 to 4,0% and at the same time the highest homeostaticity rates (Hom): in the Hoverla variety – 30,3; Tower – 22,9, Oriana – 21,1. Stability variance (S^2) > 0.
The resistance of soybean varieties to the influence of adverse environmental factors is reflected by homeostasis, that is a universal property in the system of interaction between plants and the environment. Homeostasis is an organism's ability to minimise the influence of adverse conditions of various origins (abiotic, biotic, anthropic, etc.). The criterion for the homeostaticity of plants and their groups can be considered as their ability to maintain low variability of traits. Thus, the relationship of homeostaticity (Hom) with the coefficient of variation (CV) characterises the stability of the manifestation of properties, and therefore the stability of plant organisms in changing environmental conditions (Methodology, 2011).
The thorough analysis of the evaluation of the ecological plasticity and stability of genotypes by components ai and λ showed that the varieties of the first zone according to the coordinates of the location (Oriana, Vezha, Artemida and Femida) belong to genotypes with a high response to improving the environmental conditions. Thus, such varieties are recommended for cultivation under conditions of high agrophone. In contrast, first of all, to a greater extent, the Hoverla variety, as well as Zolotysta and Amethyst, react less to changes in environmental conditions, providing stable indicators of resistance to fusarium, the manifestation of which is less dependent on changing environmental conditions and they are in the second zone according to the coordinates of the location. The stability variance also confirms the sequence of distribution of its definition in the average group constant (Fig. 3).

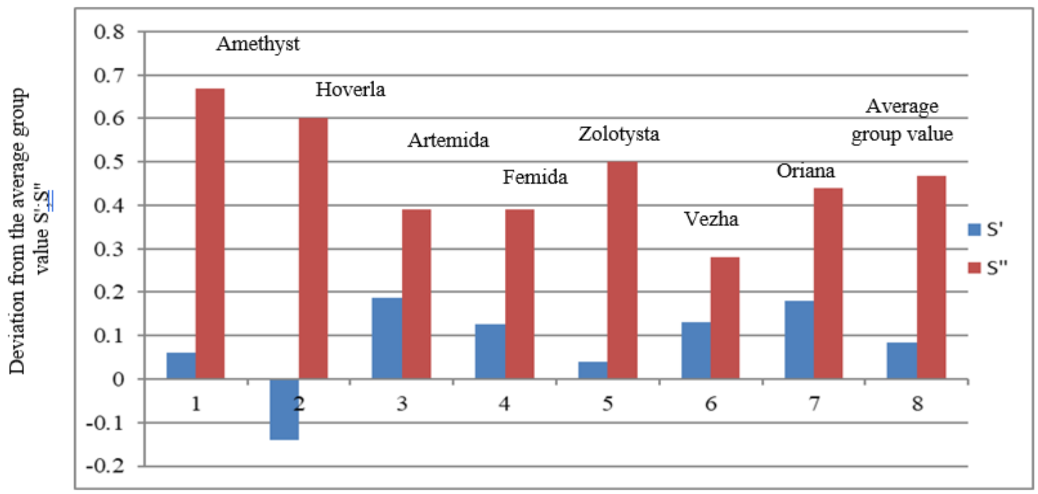

Figure 3. Stability and plasticity of soybean varieties' resistance to fusarium depending on the ecological growing conditions.

Analysis of indicators of stability and ecological plasticity determines the rate of reaction of soybean varieties for identification of the best ones compared to the worse genotypes in the sample. So, according to the grouping carried out according to the variance compared to the average group constant, the highest stability was distinguished by the varieties Hoverla, Amethyst and Zolotysta with a gradual transition from plastic – Vezha, Femida and to high-plastic – Artemida and Oriana.
According to the results of our research, a significant influence of varietal characteristics, soil and climatic conditions, as well as their interaction on resistance to bacteriosis of varieties was determined, which was reflected in the mean squares of two-factor dispersion analysis (Table 2).

Table 2. Ecological plasticity and stability of soybean varieties in resistance to bacteriosis (2010-2021).

Variety	Resistance to bacteriosis, %	Coefficient			Variance of stability (Si^2)	Hom-homeostaticity	Components	
	Year, trial sites	Ecological plasticity (bi)	Agronomic stability (as), %	Variances (v), %		Hom	a_i	λ_i
Amethyst	75,5	1,03	95,6	4,4	6,89	17,2	0,14	0,71
Hoverla	84,1	0,67	96,9	3,1	4,89	27,1	0,01	0,37
Artemida	72,8	0,92	95,9	4,1	5,16	17,7	0,1	0,38
Femida	78,6	1,13	95,7	4,3	6,11	18,4	0,19	0,49
Zolotysta	70,5	0,88	95,6	4,4	6,87	16,2	0,09	0,57
Vezha	79,7	1,26	95,8	4,2	3,79	19,2	0,24	0,47
Oriana	81,7	1,1	96,0	4,0	5,36	20,2	0,18	0,50
Factor	F *factual*	F *theoretical*			-	-		
Variety	851	2,19			-	-		
Conditions	652	1,54			-	-		
Interaction variety - conditions	27,0	1,39			-	-		

The obtained results enable evaluation of soybean varieties for determining indicators of ecological plasticity and stability using various methods. In terms of resistance to bacteriosis, soybean varieties were distinguished: Hoverla – 84,1%, Oriana – 81,7%, Vezha – 79,7 and Femida – 78,6%. It should be noted that the varieties Oriana, Vezha and Femida belong to the highly plastic ones in reaction to changes in growing conditions, (bi) > 1, and the Hoverla variety belongs to conservative in reaction to changes in hydrothermal and soil growing conditions (bi) < 1. The highest rates of homeostaticity (Hom) were found in varieties: Hoverla – 27,1, Oriana – 20,2, Vezha – 192 and Themis – 18,4. Agronomic stability (As) indicators ranged from 95.7% to 96.9%, but stability variance (S^2) > 0. Thus, in terms of adaptive ability in terms of resistance of varieties to bacteriosis in accordance with the above grouping, the Hoverla variety belongs to the first rank, since the coefficient of ecological plasticity (bi) < 1, and the variana stability (S^2) > 0, and the varieties Oriana, Vezha and Femida belong to the sixth rank, as they have (bi) > 1, and the variance of stability (S^2) > 0.

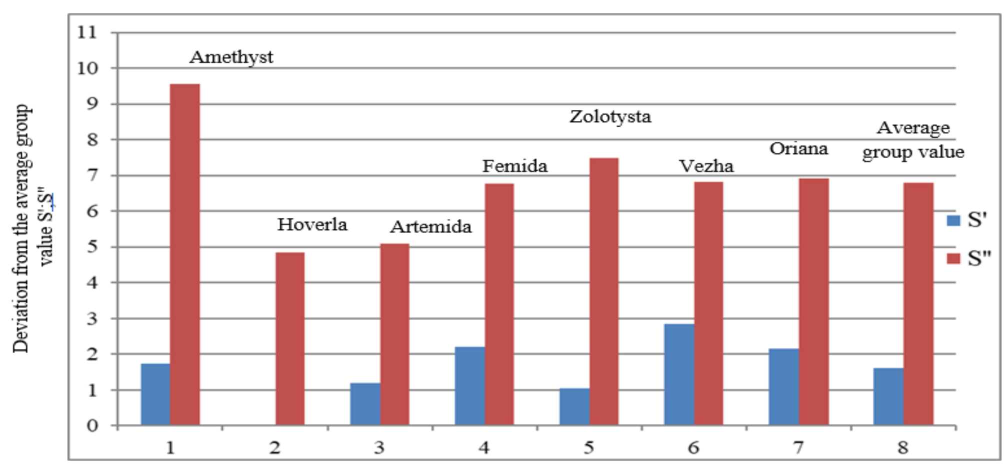

Figure 4. Stability and plasticity of soybean varieties' resistance to bacteriosis depending on the ecological growing conditions.

The analysis of indicators of varieties' ecological plasticity and stability in the expression of the components ai and λ confirmed that the varieties Femida, Oriana and Vezha belong to genotypes with an improved response to changes in growing conditions. Namely, they must be recommended for cultivation in conditions of high agrophone and favourable hydrothermal regime. However, with the deterioration of growing conditions, stable indicators decrease. Opposite to them in reaction to the change in the hydrothermal regime were the varieties Hoverla and Zolotysta, which are less responsive to changes in environmental conditions.

Confirmation of the sequence of variety distribution in the average group constant is the representation of the variance of stability. Since the reaction rate of the presented varieties allows to identify the best varieties in the sample compared to the worst ones, that is explained by the analysis of the value of stability and plasticity (Fig. 4).

The variance from the average group constant is a stability indicator: in case of positive expression and quantitative growth, the variety is determined to be highly plastic; for deviations with a maximum approximation to zero, it indicates the plasticity of the variety, and a negative value, compared to the average value, characterises the variety as stable. So, according to the presented grouping, according to the variance from the middle group constant, the highest plasticity was distinguished by the Vezha, Oriana and Femida varieties, as for the Amethyst and Artemida varieties – there is a gradual transition from high-plastic to plastic, at the same time, Hoverla and Zolotysta are assigned to the group of soybean varieties from plastic to stable.

CONCLUSIONS

- Thus, the most valuable for production conditions are soybean varieties which have a high potential for disease resistance and a stable manifestation of these properties under various hydrothermal and soil conditions. In terms of resistance to diseases of fusarium and bacteriosis during the research period, varieties Hoverla – 86,6 and 84,1%, Oriana – 83,7 and 81,7% and Vezha – 81,2 and 79,7%, respectively, revealed themselves in different ecogradients. The Hoverla variety was distinguished by a conservative reaction to changes in environmental conditions, providing a high sustainable indicator of stability, and the Oriana and Vezha varieties belonged to highly plastic, which responded well to improved growing conditions. However, taking into account the highest quantitative values of disease resistance of these varieties over a long period of cultivation in different ecogradients, they were defined as the adaptive ones, since they had the highest compliance of the plant's genotype with the real conditions of existence for a long time in order to maximise the potential for resistant characteristics to pathogens among the varieties presented in the experiment.
- The introduction and widespread cultivation of disease-resistant varieties into production will reduce the anthropogenic load on the environment due to the use of fewer chemical pesticides and will help reduce the accumulation of harmful substances in soils and agricultural products.

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